AN OVERVIEW OF THE MINERALOGY OF THE NEZILOVO, MACEDONIA DISTRICT AS COMPARED TO THE FRANKLIN, NEW JERSEY DEPOSITS

SENIOR THESIS

DEPARTMENT OF GEOLOGY AND MINERALOGY

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INTRODUCTION

The Franklin-Sterling Hill district in New Jersey has long been noted for its unique mineralogy and minable concentrations of zinc, iron, and manganese. In recent years the Nezilovo district in southern Yugoslavia has come under some scrutiny as possibly being a deposit of similar origin and composition. Little work seems to have been done in the Nezilovo area. From optical and X-ray examination of several rock specimens collected from this locale, the basic mineralogy and possible relationship to Franklin will be discussed.

FRANKLIN SUMMARY

The Franklin-Sterling Hill area lies about 50 km west of New York City just on the western boundary of the New Jersey Highlands and is bounded by 74°30' and 74°45' longitude and 41° and 41°15' north latitude lines.

The deposits of this area first came to attention in 1640 shortly after the establishment of New Amsterdam. Little was done in the area until 1848 when the Sussex Zinc and Copper Mining and Manufacturing Company was created with the purpose of exploiting these deposits. In 1897 after much litigation over conflicting titles, this company and several others united to form the New Jersey Zinc Company which still actively mines this region.

In 1954 the Franklin mine was completely worked out. It is estimated that 22-23 million tons of ore were recovered from the Franklin mine over its years of production. This ore averaged 19.6 percent Zn, 8.7 percent Mn, and 17 percent Fe. (Frondel, 1974, p. 157.) The nearby Sterling Hill mine began production shortly after 1912 and is still a source of high grade zinc ore. In 1973 alone, New Jersey records having produced 33,027 short tons of zinc with Sterling Hill being undoubtedly a major supplier. (Minerals Yearbook, p. 1329.)

The most widely accepted theory of origin of the Franklin deposits is that of Baum and Frondel (1974). Some of the original sediments were terrigenously derived and deposited in a marine environment. These are now analogous in many respects to metamorphosed sedimentary manganese deposits found elsewhere. Evidence shows that other constituents were probably chemical sediments formed by submarine hot springs. All of these sediments were deposited contemporaneously with a layer of limestone. During a period of high-grade regional metamorphism in the Precambrian these layers were recrystallized, folded and faulted. During the late Precambrian the region was subjected to erosion and was then later overlain by a series of Paleozoic sediments; the Cambrian Hardyston conglomerate and the Ordovician Kittatinny limestone. In the Paleozoic, the area was faulted and some minor folding occurred. This was followed by the intrusion of low-silica igneous dikes in the Triassic. (See Table 1.)

Table 1. Stratigraphic Column, Franklin–Sterling Hill Area

Age	Formation	Remarks	Thickness
Cambro-Ordovician	Kittatinny	Mostly dolomitic limestone, in part shaly or sandy	2,500–3,000 ft?
Lower Cambrian	Hardyston	Conglomerate and quartzite	30 ft ±
Precambrian	Pochuck Gneiss Series	Interlayered hornblende gneiss, microcline gneiss, locally with garnet or graphite, also local quartzite	Over 2,000 ft
	Wildcat Marble	Coarsely crystalline marble	300 ft
	Cork Hill Gneiss	Similar to Pochuck Series	800–1,000 ft
	Franklin Marble	Coarsely crystalline marble, locally dolomitic	1,100–1,500 ft
	Median Gneiss	Chiefly biotite gneiss	50–300 ft
	Franklin Marble	As above	Unknown, over 500 ft?
	Hamburg Mountain Gneiss	Similar to Pochuck Series, intruded by Byram hornblende granite	Over 2,000 ft?

Data from Hague et al. (1956), Baker and Buddington (1970), and Spencer et al. (1908). (Frondel and Baum, p 160)

The Franklin and Sterling ore bodies both dip about 55^{o} to the southeast.

At Franklin the ore body assumes the shape of a synclinal fold with unequal axes. The fold strikes northwest and plunges 25^{o} southeast. The west limb of the syncline has the longest exposure, 8 km. It varies in thickness from 4.5 m to 27 m, generally thickening toward the keel. The eastern limb has the shorter exposure of 183 m giving the outcrop a hook-shaped appearance.

The ores lie in the Franklin limestone within a few meters of the eastward-dipping contact between the Franklin limestone and the adjacent gneisses on the west. (See Figure 1.)

At Sterling the east limb of the fold is longest, parallels the west, and is overturned. Again contained in

FRANKLIN ZINC-IRON-MANGANESE DEPOSIT, NEW JERSEY

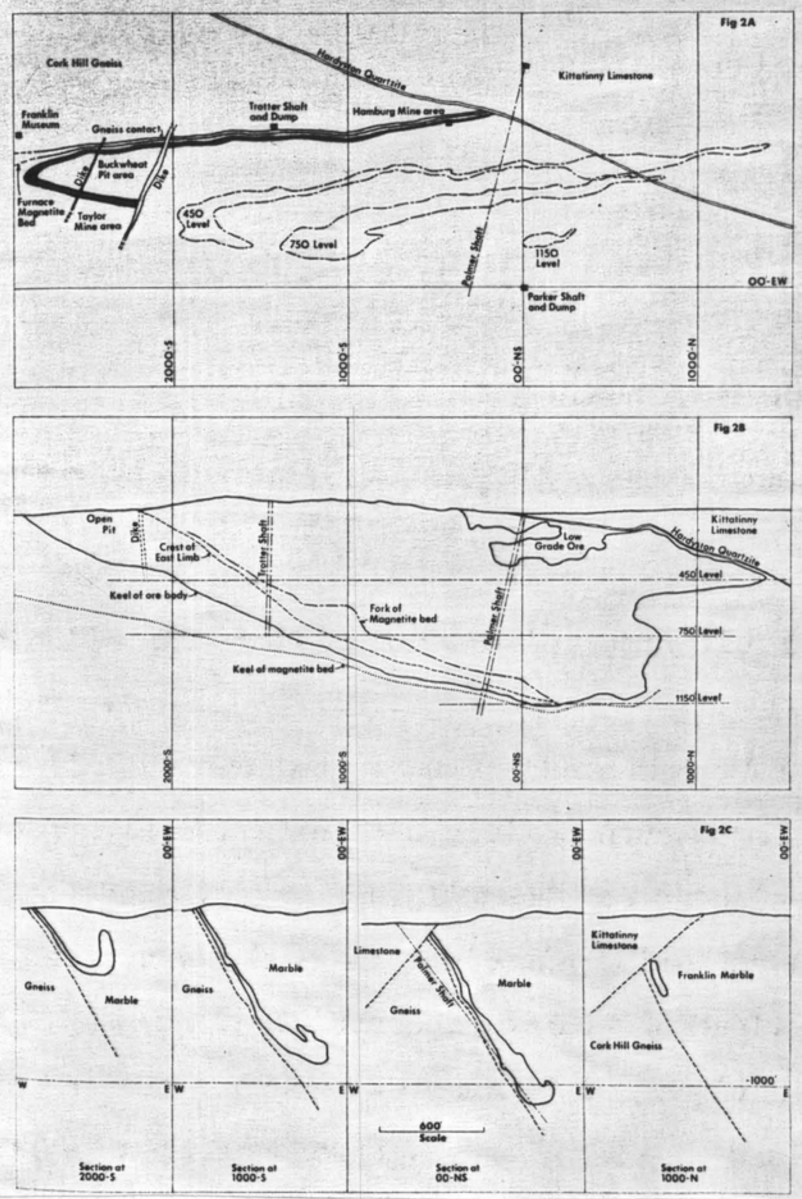


FIGURE 1. Plan, longitudinal elevation, and vertical cross sections of the Franklin ore body. Map coordinates north-south and east-west; zero coordinate at Parker Shaft. Scale in feet. Figure 2B is projected on an arbitrary north-south vertical plane. Adapted from maps by A. W. Pinger (1950) and C. H. Stockwell, New Jersey Zinc Company, 1951. (Frondel and Baum, p.161)

the Franklin limestone, the ore is located 122 to 244 m from the contact between the limestone and adjacent gneisses. The ore body extends to a depth of 762 m.

The two ore bodies are presently separated by 5 km, but were from all indications at one time continuous.

The internal structure of the ore bodies is quite complex. It consists of lenslike or tabular layers of ore and scarn ranging from a few meters to 9.1 meters in thickness. Some of the thinner scarn bodies show boudinage structure. Small intrusive bodies of pegmatite may also be seen irregularly interspersed throughout the ore bodies. (See Map 1.)

The ore bodies display prominent faulting and jointing with the principle jointing direction being N 30°E. The joints often contain a variety of low-temperature hydrothermal minerals including Mn and Zn minerals as well as calcite and serpentine.

In general the ore is too thinly layered to be separately and selectively mined except at one unique location in the Sterling ore body where a cross vein cuts between the two limbs of the fold. Here a vein of high grade black willemite occurs.

The list of minerals found in the Franklin-Sterling Hill deposits follows in Table 2. The main ore consists of 40 percent franklinite, $(Zn,Fe,Mn)O \cdot (Fe,Mn)_2O_3$; 23 percent willemite, $2ZnO \cdot SiO_2$; and less than 1 percent zincite, ZnO. The remainder is a gangue of silicates and carbonates.

Table 2. Minerals of the Franklin and Sterling Hill Deposits

Actinolite: S
Adamite: W
Aegirine-augite: S
Allactite: V
Alleghanyite: O, V
Andradite: S, AS
Anglesite: W
Anorthite: M
Anorthoclase: S
Antigorite: AS, V
Apatite: O, S
Aragonite: W
Arsenopyrite: O, M
Augite: S
Aurichalcite: W
Axinite: AS, V
Azurite: W
Bannisterite: S
Barite: S, V
Barylite: S
Barysilite: AS
Bementite: AS, V
Biotite: S
Bornite: V
Brochanthite: W
Brucite: V
Cahnite: V
Calcite: O, S, AS, V, M
Celestite: V, AS
Celsian: S
Chalcocite: V
Chalcophanite: W
Chalcopyrite: V
Chondrodite: M
Chrysocolla: W
Chrysotile: AS, V
Clinohedrite: V
Copper: V, AS
Corundum: M
Cryptomelane: W
Cummingtonite: S
Cuprite: V, W
Datolite: AS, V
Diopside: S, M
Djurleite: V
Dolomite: V, M
Edenite: S
Epidote: S
Esperite: S
Ferroschallerite: S
Fluoborite: V, AS
Fluorite: O, S, V
Franklinite: O, S, AS, V
Friedelite: S, V
Gahnite: S
Galena: V
Ganophyllite: AS, V
Glaucochroite: S
Goethite: W
Graphite: M
Grossular: S
Hancockite: AS, V
Hardystonite: S
Hastingsite: S
Hedyphane: S, V
Hematite (specular): S, AS
Hendricksite: S
Hetaerolite: V
Hodgkinsonite: V
Hortonolite: O
Hyalophane: S
Hydrohetaerolite: W
Hydrozincite: W
Johannsenite: S
Kaolinite: W
Kutnahorite: V
Lead: As, V
Leucophoenicite: O, V
Linarite: W
Löellingite: O
Magnesioriebeckite: V
Magnetite: O
Malachite: W
Manganberzeliite: V
Manganosite: S
Manganpyrosmalite: V
Margarite: M
Margarosanite: AS
McGovernite: AS, V
Melanterite: W
Microcline: S
Mooreite: AS, V
Nasonite: AS, V
Nontronite: W
Norbergite: M
Orthoclase: S
Paragasite: S
Pectolite: AS
Phlogopite: M
Prehnite: AS
Pyrite: V, M
Pyrochroite: V
Pyrrhotite: S, M
Quartz: S
Rhodochrosite: V
Rhodonite: O, S, V
Roeblingite: AS
Roepperite: O
Rosasite: W
Sauconite: W
Scapolite: M
Schallerite: V
Scheelite: M
Serpentine: AS, V
Siderite: V
Smithsonite: W
Sonolite: O, S
Spessartine: S
Sphalerite: O, V
Spinel: M
Stilbite: V
Stilpnomelane: V
Sussexite: S, V
Svabite: O, S
Talc: S, AS, M
Tephroite: O
Thomsonite: AS, V
Titanite: M
Todorokite: W
Tourmaline (dravite): M
Tremolite: S, M
Vesuvianite: S
Vredenburgite: O
Willemite: O, S, AS, V
Wollastonite: S
Woodruffite: W
Xonotlite: AS
Zincite: O

Key to types of occurrence: O = primary ore, S = calcsilicate bodies, AS = hydrothermally altered calcsilicate bodies, V = hydrothermal veins, W = weathering products, M = Franklin marble.
The list excludes varietal terms and numerous rare minerals.

(After Frondel and Baum, p 170)

In the mineralogy, Fe^{+3} and Mn^{+2} predominate.

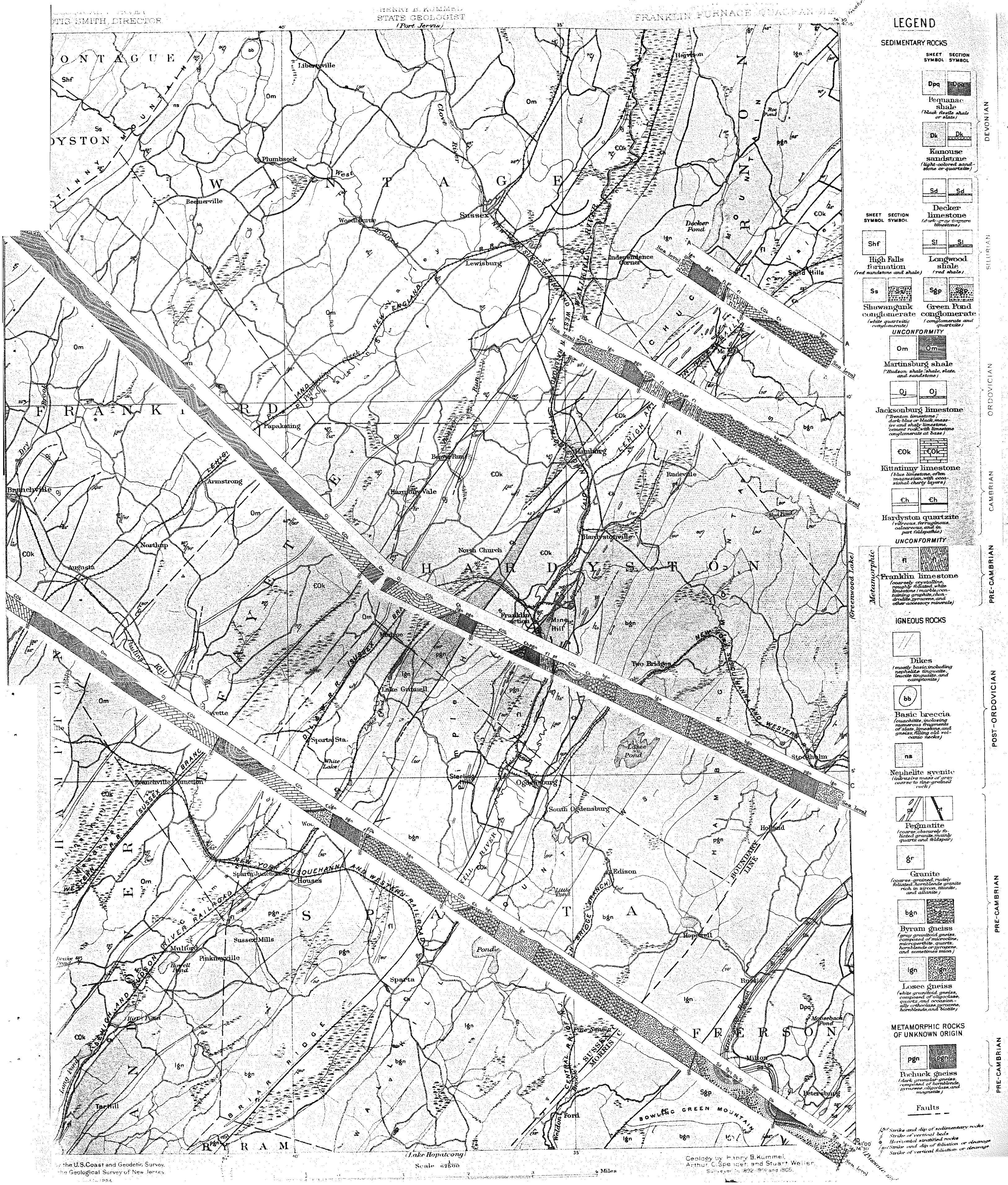
SUMMARY OF NEZILOVO

The village of Nezilovo lies in the southern political province of Yugoslavia known as the Peoples' Republic of Macedonia. This is 38 km southward of the Macedonian capital Skopje. (See Map 2.) A geologic formation exists here which is believed to be similar in origin and perhaps in mineralogy to the Franklin area. If similar deposits should be found in this area it would undoubtedly be a boon to Yugoslavia's available natural resources and economy. Little information was available concerning this region. Different sources in Yugoslavia were asked for additional information, but as yet none have responded. From the general structure map of Yugoslavia the deposit would seem to be located in an anticlinal fold plunging north-northwestward. (See Map 3.) The area seems to be intensely folded, faulted and metamorphosed. This would certainly seem to be a likely candidate for mineralization. It is presumed that no mining is currently taking place in the area.

METHODS OF APPROACH

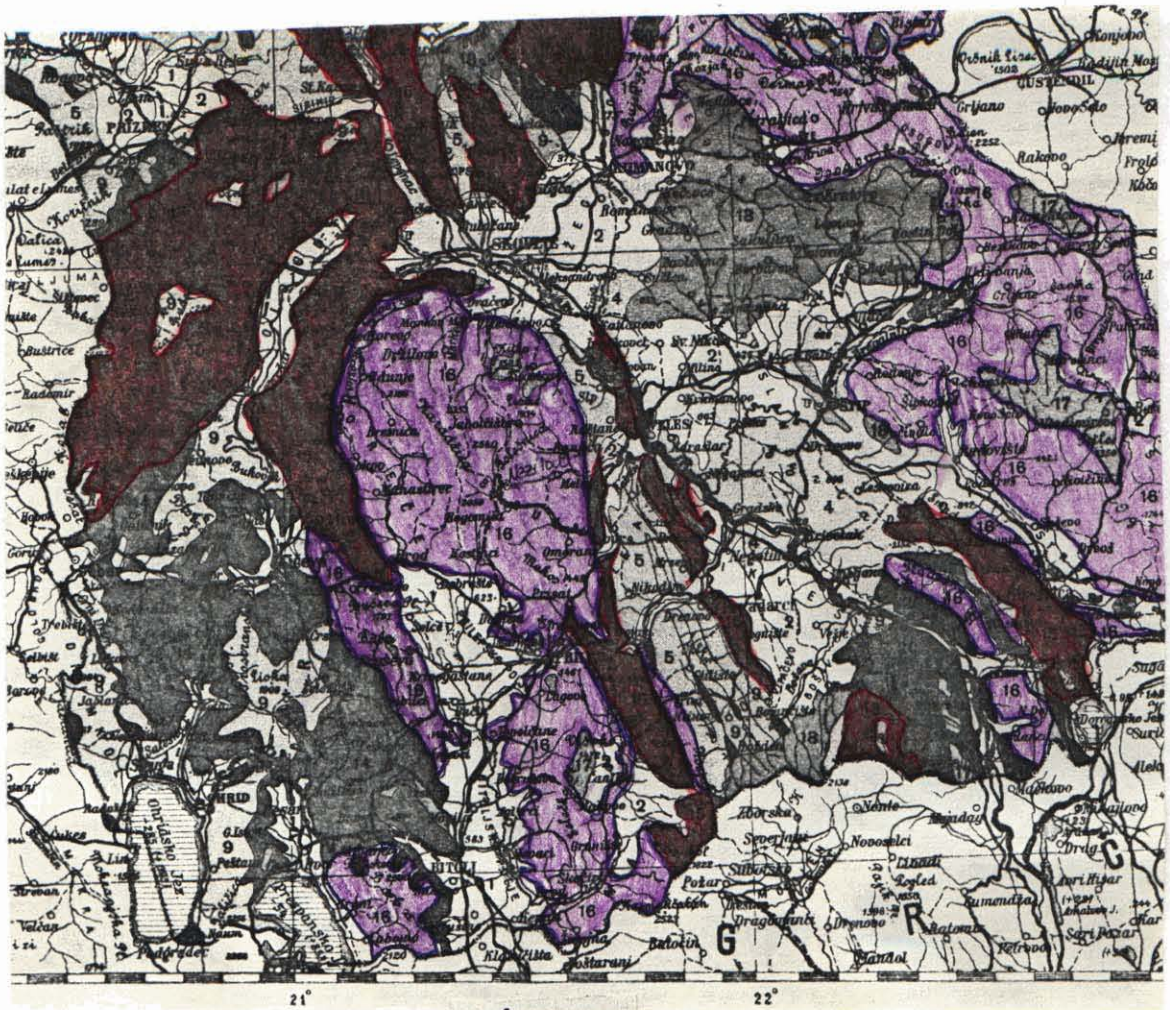
For this research, six hand specimens were obtained from Dr. Ernest Ehlers who collected these specimens on a trip to Yugoslavia. The specimens were collected within 12 m of each other.

Small portions of each rock were crushed and


OTIS SMITH, DIRECTOR
HENRY B. KUMMEL
STATE GEOLOGIST
(Port Jervis)
FRANKLIN FURNACE QUADRANGLE
LEGEND
SEDIMENTARY ROCKS
SHEET SYMBOL
SECTION SYMBOL
Dpq
Pequanac shale
(black fissile shale or slate)
Dk
Kanouse sandstone
(light-colored sandstone or quartzite)
DEVONIAN
Sd
Decker limestone
(dark-gray impure limestone)
Shf
High Falls formation
(red sandstone and shale)
Sl
Longwood shale
(red shale)
Ss
Shawangunk conglomerate
(white quartzitic conglomerate)
Sgp
Green Pond conglomerate
(conglomerate and quartzite)
SILURIAN
UNCONFORMITY
Om
Martinsburg shale
("Hudson shale," shale, slate, and sandstone)
Oj
Jacksonburg limestone
("Trenton limestone," dark-blue or black, massive and shaly limestone, "cement rock," with limestone conglomerate at base)
ORDOVICIAN
€Ok
Kittatinny limestone
(blue limestone, often magnesian, with occasional cherty layers)
€h
Hardyston quartzite
(vitreous, ferruginous, calcareous, and in part feldspathic)
CAMBRIAN
UNCONFORMITY
Metamorphic
fl
Franklin limestone
(coarsely crystalline, roughly foliated, white limestone (marble) containing graphite, chondrodite, pyroxene, and other accessory minerals)
PRE-CAMBRIAN
IGNEOUS ROCKS
Dikes
(mostly basic, including nephelite tinguaite, leucite tinguaite, and camptonite)
bb
Basic breccia
(ouachitite inclosing numerous fragments of slate, limestone, and gneiss, filling old volcanic necks)
ns
Nephelite syenite
(intrusive mass of gray coarse to fine-grained rock)
POST-ORDOVICIAN
pt
Pegmatite
(coarse, obscurely foliated granite, mainly quartz and feldspar)
gr
Granite
(coarse-grained, rudely foliated, hornblende granite rich in zircon, titanite, and allanite)
bgn
Byram gneiss
(gray granitoid gneiss, composed of microcline, microperthite, quartz, hornblende or pyroxene, and sometimes mica)
lgn
Losee gneiss
(white granitoid gneiss, composed of oligoclase, quartz, and occasionally orthoclase, pyroxene, hornblende, and biotite)
PRE-CAMBRIAN
METAMORPHIC ROCKS OF UNKNOWN ORIGIN
pgn
Pochuck gneiss
(dark granular gneiss, composed of hornblende, pyroxene, oligoclase, and magnetite)
PRE-CAMBRIAN
Faults
Strike and dip of sedimentary rocks
Strike of vertical beds
Horizontal stratified rocks
Strike and dip of foliation or cleavage
Strike of vertical foliation or cleavage
MONTAGUE
HARDYSTON
WANTAGE
FRANKFORD
LAFAYETTE
SPARTA
HAMPTON
ANDOVER
BYRAM
JEFFERSON
KITTATINNY MOUNTAIN
POCHUCK MOUNTAIN
HAMBURG MOUNTAIN
BRIAR RIDGE
BOWLING GREEN MOUNTAIN
Libertyville
Plumbsock
Beemerville
Woodbourne
Sussex
Lewisburg
Independence Corner
Decker Pond
Sand Hills
Papakating
Hamburg
Rudeville
Beaver Run
Harmony Vale
Branchville
Armstrong
Northup
Augusta
North Church
Hardystonville
Franklin
Mine Hill
Monroe
Lake Grinnell
Two Bridges
Lafayette
Sparta Sta.
White Lake
Sterling Hill
Ogdensburg
Lake Pond
Stockholm
South Ogdensburg
Branchville Junction
Holland
Edison
Sparta Junction
Houses
Sussex Mills
Mulford
Pinkneyville
Hopewell
Sparta
Russia
Milton
Petersburg
Ford
Tarthill
Long Pond
Drake Pond
Howell Pond
Mohawk Pond
Mud Pond
Roe Pond
Clove River
Papakating Creek
Pauline Kill
Wallkill River
Dry Brook
NEW YORK SUSQUEHANNA AND WESTERN RAILROAD
LEHIGH AND NEW ENGLAND
LEHIGH AND HUDSON RIVER RAILROAD
SUSSEX BRANCH
CENTRAL R.R. OF N.J.
OGDENSBURG BRANCH
BOUNDARY LINE
(Greenwood Lake)
(Lake Hopatcong)
Sea level
by the U.S. Coast and Geodetic Survey,
the Geological Survey of New Jersey
Scale 1/62500
4 Miles
Geology by Henry B. Kummel,
Arthur C. Spencer, and Stuart Weller
Surveyed in 1892-1901 and 1905.

КУМАНОВО
СКОПЈЕ
ТЕТОВО
Петровец
Катланово
ТИТОВ ВЕЛЕС
ШТИП
Кадрифаково
Ново Село
Злетово
Пробиштип
Кратово
Богомила
Гостиражни
Росоман
Неготино
КАВАДАРЦИ
Демир Капија
ПРИЛЕП
Долнени
Крушево
Кривогаштани
М. Коњари
Топлчани
Канатларци
Добрушево
Могила
Кукуречани
БИТОЛА
Логоварди
Буково
Новаци
Агларци
Гнеотино
Кременица
Живојно
ОХРИД
Ресен
Подмочани
Отешево
Асамати
Љубојно
ПРЕСПАНСКО ЕЗ.
МАЛО ЕЗ.
ЛЕРИН
Баница
Острово
ВОДЕН
Ертокоп
Суровичи
Билишти
КОРЧА
НЕГУШ
ВАРДАР
БИТОЛСКО ПОЛЕ
ПРИЛЕПСКО ПОЛЕ
21° 00'
21° 30'
22° 00'
Автомобилски пат I ред
Автомобилски пат II ред
Автомобилски пат III ред
КОНУСНА ПРОЈЕКЦИЈА
1:500.000
Км 10 5 0 10 20 30 40 50 Км

ГЕОКАРТА



LÉGENDE.

1 *Quaternaire.*

2 *Néogène.*

3 *Les couches oligocennes d'eaux douces.*

4 *Paléogène.*

5 *Crétacé superieur.*

Crétacé inférieur.

7 *Jurassique moyen et superieur.*

Jurassique inférieur. (Lias).

9 *Trias moyen et supérieur.*

Trias inférieur.

Phtanites.

12 *Permien (grès rouges).*

13 *Permo-carbonifère.*

Carbonifère.

Paléozoïque en général (schistes cristallins du II^me groupe)

16 *Schistes cristallins (du I^er groupe).*

17 *Granites.*

18 *Andézites et roches trachytiques.*

Diabases et melaphyres.

Gabbros et serpentines.

IZDANJE KNJIŽARE FRANJE BACHA, BEOGRAD (1930-1931)
Geološka Karta Kraljevine Jugoslavije

MAP 3

separated. Nonopaque minerals were then crushed to between 100 and 200 mesh size and analysed optically. Opaque and semi-opaque minerals were crushed to less than 325 mesh and were analysed by X-ray powder diffraction method. (See Table 3.) The X-ray machine was equipped with a copper tube with nickel shielding. The machine was set on a coarse adjustment of 1500 volts in the high voltage selector and on 35 kilovolts and 15 milliamps for the power generation. The crushed material was moistened with a water and Duco Cement solution to afix it to the slide for analysis.

Baric (1960) reports the presence and characteristics of gahnite, piedmontite, and rutile from this locale.

In this investigation the following minerals were isolated: albite, $Na_2O \cdot Al_2O_3 \cdot 6SiO_2$; alurgite, $K_2MgAl_4Si_7O_{22}(OH)_2$; barite, $BaSO_4$; biotite, $K_2(Fe,Mn,Mg)_4(Al,Fe)_4Si_6O_{22}OH_2$; dolomite, $CaO \cdot MgO \cdot 2CO_2$; epidote, $4CaO \cdot 3(Al,Fe)_2O_3$; gahnite, $(Zn,Mn)O\ Al_2O_3$; hematite, Fe_2O_3; magnetite, Fe_3O_4; microcline, $K_2O \cdot Al_2O_3 \cdot 6SiO_2$; muscovite, $(Na,K)_2Al_6Si_6O_{22}(OH)_4$; piedmontite, $4CaO\ 3(Al,Fe,Mn)_2O_3 \cdot 6SiO_2 \cdot H_2O$; quartz, SiO_2; rutile, TiO_2; and talc, $3MgO\ 4SiO_2\ H_2O$. (See Table 4.)

CONCLUSIONS

All of the minerals found in this investigation from the Nezilovo area have been found at Franklin with the exception of piedmontite and alurgite. More attention should be paid to the minerals that were not present, particularly the ore minerals which occur at Franklin: franklinite, willemite, and zincite.

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RESULTS OF X-RAY ANALYSIS

Mineral	Composition	Degrees Rotation Inspected	Peak Location	d	Relative Intensity
GANNITE	$(Zn,Mn)O \cdot Al_2O_3$	5° – 82°	36.7°	2.4487	100%
			59.0°	1.5655	85%
			31.2°	2.8666	65%
			64.9°	1.4367	35%
			65.0°	1.4347	30%
			55.4°	1.6584	20%
			77.0°	1.2383	15%
			44.6°	2.0316	10%
			77.2°	1.2356	10%
			44.8°	2.0230	8%
HEMATITE $\bar{c}$ MAGNETITE	Fe_2O_3 Fe_3O_4	5° – 60°	33.1°	2.7063	100%
			49.4°	1.8448	60%
			54.0°	1.6980	55%
			35.7°	2.5149	50%
			24.1°	3.6926	40%
			27.9°	3.1977	35%
			46.5°	1.9529	25%
			40.8°	2.2116	25%
DOLOMITE WITH IRON	$CaO \cdot MgO \cdot 2CO_2$	25° – 76°	30.9°	2.8938	100%
			51.0°	1.7906	40%
			50.5°	1.8072	25%
			41.1°	2.2012	22%
			35.3°	2.5425	10%
			33.5°	2.6749	10%
			44.9°	2.0187	9%
			65.1°	1.4328	8%
			63.4°	1.4670	8%
			59.8°	1.5465	5%

TABLE 3.

NEŽILOVO MINERALS

Mineral	X-Ray Analysis Done	Composition	β or ω Index	2V	Sign	Biref.	Cleavage	Megascopic Color	Microscopic Color	Misc.
1. Albite		$Na_2O \cdot Al_2O_3 \cdot 6SiO_2$	1.53 β	74°	+	.011	{010} {001} perf.	White	White-Clear	Polysyn. Twin. Some grains
2. Alurgite		$K_2Mg_2Al_4Si_7O_{22}(OH)_2$	1.59 β	~15°	—	.046	{001} mic	Red	Pink	
3. Barite		$BaSO_4$	1.64 β	37°	+	.013	{001}{110} perf, {010} imp.	White	White-Clear	
4. Biotite		$K_2(Fe,Mn,Mg)_4(Al,Fe)_4Si_6O_{22}(OH)_2$	1.63 β	~10°	—	.050	{001} emin	Black	Almost opaque black	
5. Dolomite	*	$CaO \cdot MgO \cdot 2CO_2$	1.68 ω	0°	—	.181	{10$\bar{1}$1} perf	Brown	Clear with brown stain	In some cases min. was clear with pink cast
6. Epidote		$4CaO \cdot 3(Al,Fe)_2O_3$	1.74 β	80°	—	.028	{001} perf {100} imp	Dk. Green	Lt. Green	
7. Gannite		$(Zn,Mn)O \cdot Al_2O_3$	1.78	—	Isotropic	—	None	Green, Blue, Black	Green, Blue, Brown-Green	Varied Composition
8. Hematite		Fe_2O_3	3.01 ω	0°	—	.28	{0001} parting	Black	Bt. Red	Alteration from Magnetite
9. Magnetite	*	Fe_3O_4	—	—	Opaque	—	—	Black	Black	Magnetic
10. Microcline		$K_2O \cdot Al_2O_3 \cdot 6SiO_2$	1.53 β	83°	—	.004	{010}{001} perf	Lt. Blue	White-Clear	Tartan Twinning
11. Muscovite		$(Na,K)_2Al_6Si_6O_{20}(OH)_4$	1.59 β	42°	—	.043	{001} mic	Yellowish	Clear to yellow-green	
12. Piedmontite	*	$4CaO \cdot 3(Al,Fe,Mn)_2O_3 \cdot 6SiO_2 \cdot H_2O$	1.77 β	68°	+	.018	{001} good {100} {010}	Black	Green-Brown	Epidote Group
13. Quartz		SiO_2	1.54 ω	0°	+	.009	None	Clear	Clear	
14. Rutile		TiO_2	2.62 ω	0°	+	.287	{100} {110} distinct	Black	Dk. Brown	
15. Talc		$3MgO \cdot 4SiO_2 \cdot H_2O$	1.59 β	~15°	—	.050	{001} mic	White	White-Clear	Foliations in grains

TABLE 4

Baric (1960) lists Nezilova as a lead-zinc deposit. No lead minerals and only one zinc mineral, gahnite, were found in this investigation. Due to the limited amount of work previously done in the area and the unavailability at this time of more rock specimens to be analysed, it is impossible to tell how closely these deposits are related, though such a relationship might certainly be possible. A need for further investigation is indicated and might prove quite fruitful.

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